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Art. IV.—*The Question of Recent Emergence of the Shores of Port Phillip Bay.*

By EDWIN SHERBON HILLS, Ph.D., D.Sc.

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In spite of the definite terms in which a belief in Recent emergence of the shores of Port Phillip Bay has been expressed by some authors, the question has of late become controversial. Jutson has recently reviewed the evidence (1931), but although he adduced much new information bearing on the subject, he was unable to draw any decisive conclusion.

The author has re-examined the shores of the Bay, in order to discover criteria that might perhaps settle the matter. The eastern shores, from which little evidence concerning changes in sea level had formerly been obtained, were traversed from the Quarantine Station at Portsea to Brighton, and critical stretches of the western shores were also studied in detail. It may be stated in advance that what appears to the author to be definite evidence of Recent emergence has been observed at practically all localities where the conditions of erosion and deposition are such as to favour its preservation.

I. The Eastern Shores.

Raised Shore Platforms.

Three difficulties present themselves in the interpretation of shore platforms. Firstly, where the coast is composed of horizontal or gently dipping strata of different degrees of resistance to weathering and erosion, not only may the development of normal shore platforms between low and high water mark be interfered with, but also, rock ledges formed by resistant beds above high water mark may simulate raised abrasion platforms. This is well illustrated at Rickett's Point, where an abnormally broad shore platform has been developed on the upper surface of the resistant Red Beds, which, there, is situated between low and high water levels. The Red Beds rise towards the south, and at Table Rock a well marked ledge, above high tide level, has been produced on their upper surface by the more rapid weathering and erosion of the overlying softer rocks. With such geological conditions, especially where differential weathering and erosion are less obvious, the recognition of any slightly elevated abrasion platform that might be present is difficult.

The second difficulty is related to the amount of emergence. It is well known that no immediately obvious raised shore platforms occur around the shores of Port Phillip, and it was therefore realized that the amount of any Recent emergence which might be discovered would probably be small. Under these circumstances raised abrasion platforms might still be subjected to the attack of storm waves. They would never have been very broad, and after erosion only remnants of them would remain. These would be difficult to distinguish both from rock ledges and from irregularities in the normal shore platforms.

The third difficulty is the fundamental one that the principles underlying the development of shore platforms, even with a stationary sea level and uniform rocks, are by no means fully understood (see e.g. Bartrum, 1935). Where possible emergence or other changes in the physiographic conditions introduce complications, the interpretation of shore platforms becomes very involved, and the author realizes that more intimate studies than he has yet been able to undertake may require some modification of the ideas put forward in this paper.

Raised Shore Platforms in Granite.

Shore platforms that are regarded as "raised" abrasion platforms by the author, occur at the foot of Oliver's Hill, Frankston, and 1 mile north-east of the mouth of Tanti Creek, Mornington. At the north-eastern corner of Dromana Bay, a granite platform, whose interpretation is open to some doubt, occurs above high tide level. Throughout the descriptive portion of this paper the words "raised" and "uplifted" will be used with reference to emergence due either to eustatic movements of sea level or to tectonic movements.

At the above localities the raised platforms range up to about 3 feet above high tide level. At each there is also a well-developed abrasion platform now being cut between high and low water levels. These latter platforms are covered with a veneer of rounded pebbles and small boulders in various degrees of dispersion. In places, pebble beaches have been built up above low water mark; elsewhere the pebbles are widely scattered, and in places sand occurs on the platform.

At Frankston and Mornington water-worn pebbles rest upon the raised platforms (pl. III, fig. 1). It has been suggested to the author that these and similar high level pebble beds around the eastern bayside may be storm beaches. Evidence will be brought forward below to indicate that this is not the correct interpretation, but in the present context it is desirable to emphasize that the pebbles rest upon definite platforms, now some feet above high water level, which have been cut in uniform massive granitic rocks. Horizontal jointing in these granites cannot be regarded as determining these platforms, for the

granites of the coastline in the Frankston, Mornington, and Mount Martha districts are, with very local exceptions, extremely closely jointed and shattered by steeply dipping joint planes, major horizontal joints being absent. No obvious petrological differences between the rocks of the presumed raised platforms and of the normal platforms below them were observed.

At Frankston and Mornington the raised platforms are seen in section at the foot of the cliffs, although at Frankston part of the platform has been laid bare of its cover of pebbles and talus. In Dromana Bay, on the other hand, remnants of the presumed raised platform rise as table rocks above the normal shore platform, and are not covered with pebbles.

It may be observed in a profile view that these table rocks have a general similarity in elevation, although rising gently towards the base of the cliff. There the raised platform is better preserved (pl. III., fig. 2), and in one locality a well marked notch is situated at the junction of the cliff face with a platform remnant. The tops of the presumed platform remnants range from about 1 ft. 6 in., to 3 ft. 6 in. above the platform now being formed, and are still subject to wave attack.

Passing away from the commencement of the granite cliffs near Dromana, the platform remnants become lower and smaller, until none are preserved. Where it is well developed, the platform resembles in some respects the storm wave platforms described by Bartrum (1935), being in places above high tide level, and having a steep drop at its seaward edge, where a normal profile is developing. Storm wave platforms are, however, rarely developed in massive igneous rocks; they are found only at localities subject to very vigorous wave action, and are backed by cliffs that show no signs of weathering. It is probable, too, that a considerable tidal range aids their formation. In none of these respects are the conditions in Dromana Bay comparable. The tidal range is small, only 3 to 4 feet; the cliffs are weathered, the rocks are massive, and violent waves of an intensity commensurable with those on exposed ocean coasts are not formed in Port Phillip.

At the commencement of the cliffs (see pl. III., fig. 2, right hand side) the appearance is given that as the detrital material which overlies the granite at this point is eroded away, the cliff so exposed is not homogeneous, but has resistant rock near its base overlain by softer rock above. Some suggestion of this is also to be seen in small coves cut into the granite, and it may be that the rock of the platform is more resistant to erosion than that above it. This in turn can perhaps be related to the saturation of the rocks below high tide level, as in the formation of platforms of the Old Hat type (Bartrum, 1935). In the present instance, however, the platform is not horizontal either along the coast or in profile, and is in part above high tide level.

It must therefore be further postulated, following the above assumptions, that emergency has occurred accompanied by tilting, and that wave erosion of the resistant rock above present high tide level has produced the seaward inclination of the platform.

Raised Shore Platforms in Tertiary Sandstones.

Localities where these have been observed are as follows:—Between Grice's Creek and Davey Point; near the mouth of Tanti Creek, Mornington; and on the north side of Fisherman's Point, Mornington. These platforms are essentially similar to those in the granites at Frankston and Mornington. They are overlain by deposits of water-worn pebbles similar to those on the normal shore platforms at each locality. Their seaward edges are being eroded during storms, and thus the platforms and their covering pebble beds are seen in section at the back of the present beaches (pl. IV., fig. 3).

Between Grice's Creek and Davey Point the platform is well exposed on a small point, where a thick kitchen midden rests on the pebble bed (pl. III., fig. 3). At this point the platform is about 2 feet above average high water level. At Tanti Creek the platform is seen to rise in the cliff section south of the creek, on to the slopes of a hill. Where it is flat, nearer the creek, it is about 3 feet above high water level. Where it rises on to the hill, boulders derived as talus from the latter can be seen to rest upon the slopes. These are not water-worn, but as the slopes flatten and the pebbles pass down on to the platform, they become rounded, pitted, and covered with a ferruginous coating, exactly resembling in these features the pebbles and boulders on the present beach.

At Fisherman's Point the platform is about 5 feet above average high water level, and the base of the pebble bed that rests on it has been cemented by calcareous infiltrations.

As with the granite platforms, those cut in Tertiary sandstones at the above localities are clearly not determined by differences in the rate of weathering and erosion of the strata. In all their features, excepting their elevation above sea level, they closely resemble the platforms now in course of formation at existing sea level.

The High Level Pebble Beds.

The suggestion has been made that the pebble beds which rest upon the above-described platforms, and similar high level pebble beds at various localities around the eastern shores of the Bay, are storm beach deposits. Several considerations may be urged against this view

Firstly, it is a matter of experience and observation that no marine deposition has gone on at the level of the pebble beds for a long period of time. On the storm beach hypothesis it is necessary to postulate that the pebble beds are ancient storm beaches, and that the physiographic conditions have changed since they were built up. It is indeed clear that they formed before the aborigines began to make extensive use of the shellfish along the shores for food, since no kitchen middens underlie them. On the other hand, they are in every instance covered either by kitchen middens or by talus from the cliffs. It is evident that the platforms and pebble beds afforded dry, flat camping grounds, conveniently situated near the shore. The growth of vegetation on the middens and talus which cover the pebble beds is a further indication that for a long period they have been out of reach of the waves, except at rare intervals during severe storms. The latter, however, have in no known instance added to the deposits, but have invariably tended to erode them away.

In consideration of the evidence concerning the nature of the pebble beds and the rock platforms on which they rest, it appears reasonable to link the two, and to regard the platforms as raised abrasion platforms, the pebble beds as beach deposits formed by wave action on these platforms before they were elevated. The analogy with the platforms now being cut, is then very close.

Vegetated Cliffs.

The long stretches of vegetated cliffs that lie behind the back-shore deposits in the majority of small bays on the eastern shores of Port Phillip are considered to be of some significance in relation to uplift (pl. III., fig. 3). If the protecting beach deposits are to be regarded as due to normal progradation at present sea level, then some change in the conditions of erosion and deposition along the bayside must be postulated to account for the general cessation of erosion, except at headlands and places where the nature of the rocks or the presence of deep water offshore favours it. No reason for such a change has been put forward, and the author can suggest none. Furthermore, the nature of any such change would be the reverse of that which might be postulated to account for the high level pebble beds, if these are regarded as storm beaches. In the latter case, retrogradation must be regarded as proceeding; in the former, progradation.

On the other hand, a slight Recent uplift would fit the observed facts very well, accounting for both the raised pebble beds and the vegetated cliffs. Such an uplift would have the effect of temporarily removing the base of the cliffs from the zone of active wave attack. Before they could be again subjected to such attack, that portion of the abrasion platform which had been

raised above high water level would have to be removed. It is considered that this has occurred on the headlands and in belts of soft rock on the eastern shores of the Bay. Elsewhere various stages in the removal of the platforms are to be seen, the common condition near the headlands being shown in pl. IV., fig. 3. Here the raised abrasion platform and its covering pebble bed are exposed in section. Further from the headlands, erosion would be subordinate to deposition, and the raised platforms would be covered with blown sand or low beach ridges, forming a dry backshore zone on which vegetation could become established, so further protecting the cliffs. This is to be observed at many localities, such as Portsea, Sorrento, and Rickett's Point, where bathing boxes, boat sheds, and even dwellings have been built on the backshore deposits. In a small bay adjoining Table Rock, between Rickett's Point and Beaumaris, a pine tree is well established on the grass and scrub covered backshore.

Raised Sandy Beaches and Shell Beds.

Commencing at the "First Settlement in Victoria," near Sorrento, and extending with few interruptions to The Rocks at Dromana, is a flat stretch of country, the seaward edge of which is marked by a low cliff. This gradually descends from 8 or 10 feet above ordinary high water near Sorrento and Rye, to only 1 foot or so at The Rocks. At the First Settlement, shell beds occur near the base of this low cliff. These first appear on the flanks of a cliff composed of Pleistocene dune limestones, where unworn *Arca trapezia* occurs, together with gasteropods and paired and single valves of other pelecypods. No systematic collection from these or the other shell beds around the coast has been attempted. The specimens collected were the commonest at each locality, and they were submitted to Mr. F. A. Singleton, who kindly determined them. All are referable to species now living, but it is notable that oysters and Arcas, which are common in the shell beds, are now extremely rare in Port Phillip. Indeed it is doubtful if *Arca* now lives in the Bay, although it occurs in Western Port.

At the First Settlement the *Arca* band passes up on to the flanks of the Pleistocene dune, ascending to a height of 5 to 6 feet above ordinary high water level. It descends within about 1 chain towards the east, passing into horizontal shell beds whose upper surface is about 3 feet above average high water level. *Arca trapezia* was not obtained from these shell beds, which, however, contained numerous oysters (*Ostrea* cf. *sinuata*) and other species of mollusca which may all be collected on the present beaches.

Towards Rye the shell beds pass into well stratified beach sands containing only isolated shells. These sands have developed a calcareous *B* soil-horizon about 4 to 5 feet above

ordinary high water, and the soil is overlain by a uniform and extensive kitchen midden. Between the First Settlement and the White Cliff at Rye, old sand dunes overlie the above-described beach deposits in places. The top of the beach sands can be discerned beneath the dunes as a horizontal band which breaks the sandfall slope of the cliffs. These dunes are therefore younger than the beach sands into which the shell beds at the First Settlement pass, while these shell beds are in turn younger than the Pleistocene dunes at the latter locality. The younger dunes, although calcareous, are very little consolidated, and in many places fall away at the angle of rest of the sand, whereas the Pleistocene dunes are consolidated. At a point about 1 mile west of the Canterbury jetty, between Rye and Sorrento, fossilized bones of a bird were obtained from the younger dunes (pl. IV., fig. 2). These were examined by Mr. G. Mack of the National Museum, who states that they probably belong to a genus of Procellariiformes (Tubinares), approaching the Giant Petrel (*Macronectes*) in size. They are definitely not *Puffinus* (Mutton bird). The bones are not mineralized, and their reference to a type of bird that is still common around the coast is a further indication of the youth of the dunes as compared with those of Sorrento, from which bones of an extinct species of kangaroo have been obtained (Gregory, 1902).

In view of the above evidence and the fact that no extinct species have been obtained from the shell beds, these and the overlying dunes are both regarded as Recent.

Between Rye and The Rocks no shell beds were observed, but at all localities where exposures were visible, stratified beach deposits ranging from fine sand to coarse broken shells were found to underlie the kitchen middens and superficial sand drifts along the coast. The elevation of these beach deposits ranges up to about 4 feet above high water level. They are in places overlain by low sand ridges with intervening swales.

The above beach deposits and shell beds appear to have been originally laid down below high water mark, to judge by similar formations along the existing beaches. This is indicated by the arrangement of the shells in well-defined layers, the majority lying with their convex surfaces uppermost. The common occurrence of paired valves and of unworn shells, even of fragile types, further points to deposition below the swash mark, possibly between low and high water level, or even lower. In the beach sands the stratification is well defined by coarse and fine layers, or by black bands rich in magnetite, ilmenite, and other heavy minerals such as zircon (pl. IV., fig. 2).

There can be therefore no doubt that emergence has occurred in this district. Any suggestion that results simulating emergence might have been caused by the constriction of the mouth of

Port Phillip, due to the formation of the dunes of the Sorrento peninsula, cannot be substantiated. It has been considered that this constriction would cause a reduction of high tide level in the Bay, but the raised beach deposits are younger than these consolidated dunes, and therefore their emergence cannot be related to the above cause. The gradual fall in elevation of the raised beaches towards The Rocks indicates that their emergence was caused, at least in part, by tectonic movements.

The Cemented Band at Portsea.

An unusual feature shown in the cliffs at Point McArthur, near Portsea, is probably of some significance with regard to uplift. The calcareous Pleistocene dunes at this locality are consolidated, but about 2 feet above high tide level they are cemented by secondary calcium carbonate into an especially resistant band, which is about 1 ft. 6 in. to 2 feet thick. This hard band traverses the inclined bedding planes in the dunes indiscriminately, and, as levelled from one side of a small cove to the other, is horizontal (pl. IV., fig. 1). Beneath the resistant band a wave notch has been excavated.

The existence of the band in the cliff face, above high tide level, suggests that some change in sea level has occurred, since no factor can be suggested which would operate at such an elevation to induce cementation of the dunes. It is probable that the hard band was formed by deposition of secondary calcium carbonate in the body of fresh water that exists in the dunes at about high tide level. With a stationary sea level, the hard band would then appear in the cliffs at high tide level, and it is suggested that its present elevation of about 2 feet has been brought about by an emergence of this order of magnitude.

The Carrum Swamp.

In the district between Mordialloc and Frankston the coast is fringed with a series of sand ridges. Behind these ridges is the Carrum Swamp, which before it was drained and cultivated was about $2\frac{3}{4}$ feet above the level of highest observed spring tides at the mouth of Mordialloc Creek, or about $4\frac{1}{2}$ feet above ordinary high water. The shallow alluvium of this swamp overlies sand containing marine shells of the same species as are now found in Port Phillip. *Arca trapezia* also occurs in these sands, the level of which in the northern part of the swamp is about 3 feet or less below the present surface of the drained swamp alluvium.

The Carrum Swamp is bounded on its inland side by a second arcuate line of sand ridges, along which Wells' road runs, being so situated because the ridges are not subject to flooding as is

the land on either side. An excellent map on which the above features are shown in detail is in the possession of the Lands Department, and was used in the preparation of fig. 1.

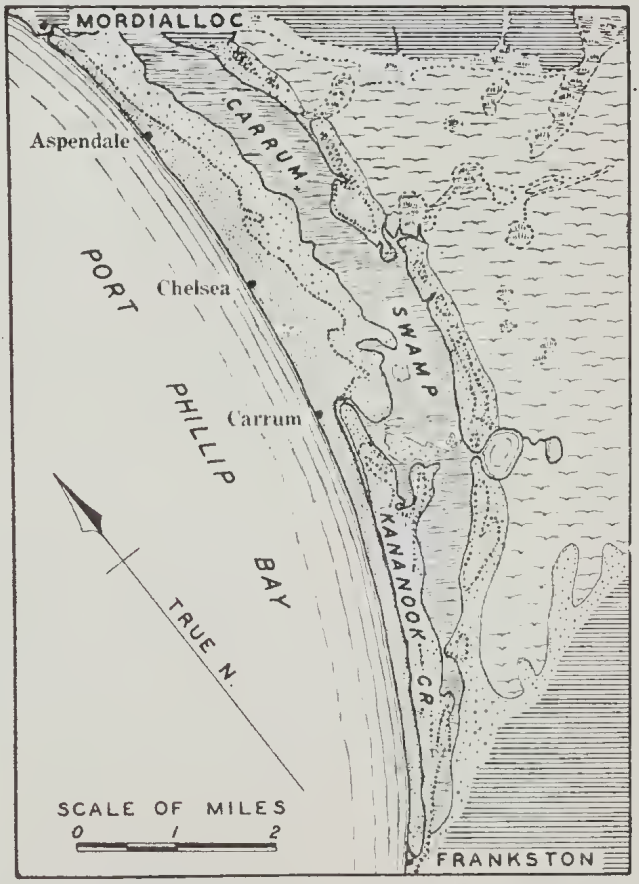

Fig. 1.—Map showing the coastal and inland sand ridges between Mordialloc and Frankston. Close stippling, high sand ridges, open stippling, low sand flats, originally covered with reeds and tea tree. Horizontal ruling, high land north and south of the swampy areas.

It is clear that at an earlier date the shoreline was situated along the Wells' road sand ridge. The retreat of the shore to its present position was then brought about by some sudden change. If this had come about by normal progradation and building of beach ridges, the latter would occur in the Carrum Swamp. No beach ridges occur there, and the sudden retreat of the sea for a distance of over 1 mile is best accounted for by postulating uplift. This is supported by the greater elevation of the alluvium behind the Wells' road ridges than that in the

Carrum Swamp (10 feet above highest spring tides as against $2\frac{3}{4}$ feet). The shell beds may have been uplifted, or they may have been laid down in a lagoon formerly situated between the Wells' road sand ridges and those along the new coastline. It is difficult to decide on this point in view of the settling down of the swamp deposits since they have been drained.

The course of the Kananook Creek, which is diverted southwards near Carrum and flows for $4\frac{1}{2}$ miles parallel to the coast, to reach the sea at Frankston, is notable. The creek occupies a marshy depression between two well-defined but complex sand ridges whose origin is not yet clear. It is highly improbable that the creek should have suffered such an extensive diversion simply as a result of the formation, by normal progradation, of a series of beach ridges barring its mouth. It occupies an unbroken trough between the two main ridges, and is too sluggish to have cleared this for itself, being only at about sea level throughout its length. A slight uplift after the formation of an earlier coastline along the seaward edge of the ridge along which the railway runs at Seaford would, however, have probably led to the formation of the second ridge, on which the Point Nepean road is situated, leaving a swale between the two. This would be then used by the creek.

The Yarra Delta.

On the map published by Selwyn (1854), the superficial deposits of the aggraded area at the head of Hobson's Bay, known as the Yarra Delta, are described as "Recent upheaved estuary bottom, consisting of beds of sand and clay with recent shells resting on red Tertiary sandstone." Sections given by Selwyn (1854) and by Lucas (1887) show that the surface of the sand formations fringing the seaward edge of the West Melbourne Swamp rises to $7\frac{1}{2}$ to 10 feet above high water level. Parallel ridges described as "blown sand" are more probably beach ridges, as described by Jutson (1931), and these rest upon "sands and Recent shells." These sands are in places current bedded, and are regarded as marine by Selwyn and Lucas. They are 2 feet above high water level in some parts.

II. The Western Shores.

As remarked upon by Jutson, these are physiographically distinct from the eastern shores, long stretches being flat and undergoing progradation, while the eastern shores are cliffed in many places. An important area which has been much discussed is that between the Williamstown Racecourse and the Military Reserve at Altona. Near the Williamstown Racecourse occur the so-called Altona shell beds, which have been described by Hall and Pritchard (1897), Grant and Thiele (1902), Pritchard (1909, 1910), and by Jutson (1931). The shells are all of

living species, and all palaeontologists who have referred to them agree that they are Recent (see Singleton, 1935). Grant and Thiele showed that the shell beds are 8 feet thick, the top being $7\frac{1}{2}$ feet above high water level. I am informed by Dr. H. S. Summers, who collaborated in the levelling, that the datum used was the swash mark of the highest observed tides in the neighbourhood. These authors noted that the shells occur in distinct layers, with marine and estuarine types interbedded. They concluded that the beds are therefore not storm beaches, and that an uplift of at least 10 feet has taken place since they were deposited. Pritchard, however, decided that they are storm beaches, and Jutson described them as beach ridges probably formed by storm waves at existing sea level.

In regard to their nature, the following points are of importance. The beds are well stratified and not current bedded. Individual bedding planes can be traced for some yards both parallel to and at right angles to the coast. They contain thin-shelled forms in a perfect state of preservation, and a majority of the concavo-convex shells lie with their convex surfaces uppermost, indicating that they were deposited below high water level, out of reach of the turbulent swash of waves breaking on the beach. These features are in the author's opinion quite sufficient evidence that the beds are not storm beach ridges, for in these stratification is typically irregular, or even absent, and thin-shelled forms are broken.

The relationship of the beds to the other shell and sand ridges of the district is also significant. Jutson has given a general description of these ridges, and of the associated swamp deposits with marine shells that occur on the beds of three shallow ephemeral lakes in the Altona district. This district has been mapped on a scale of 200 feet to 1 inch under the direction of the author, and fig. 2 is based on this work. In the vicinity of Altona and Seaholme townships the ridges have been disturbed and cannot be traced in detail. North-east of Seaholme the ridges are composed in part of shelly limestone similar to the type locality near the Williamstown Racecourse (fig. 2), and in part of sand with scattered shells. The ridges rest upon the surface of the Newer Volcanic basalt, which appears in some of the intervening troughs. Along the seaward edge of the basalt is a rather sudden drop of a few feet to an area of tidal flats and low beach ridges, the land on the higher side of this drop being entirely out of reach of wave action at existing sea level. This stretch of coast faces the south-east, a quarter from which storm winds are extremely rare. The fetch of such winds is also relatively short, and the water offshore is very shallow. It is therefore scarcely conceivable that storm waves of sufficient intensity to flood the basalt plain, and to deposit beach ridges on it up to 8 feet above the highest known high water mark,

FIG. 2.—Map of the sand and shell ridges in the Altona district.

should ever have been generated in this area under the existing conditions. Furthermore, even if such a possibility could be entertained, no good reason can be suggested for the formation of an orderly succession of such ridges at gradually decreasing elevations towards the coast.

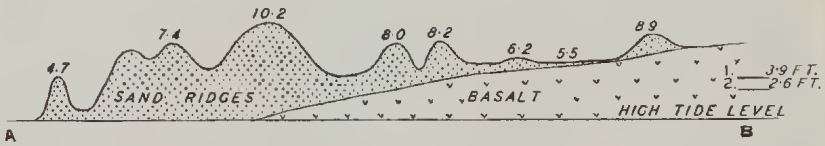

Fig. 3.—Section along the line *A–B* in Figure 2. Vertical scale, 1 in. = 22 ft.; horizontal scale, 1 in. = 14 chains. 1. Elevation of marine shells *in situ* in muds, Lake Truganina. 2. Elevation of redistributed marine shells on the bed of Lake Truganina.
Note.—The ridge nearest *A* is a beach ridge formed at existing sea level.

The view that these ridges are not beach ridges is further supported by their external form. A beach ridge is typically high compared with its breadth, owing to its formation by waves breaking within a narrow zone along the foreshore.

The ridges at Altona and Seaholme, on the other hand, are relatively low and broad. A ridge 4 chains wide is, for example, only 4 or 5 feet above the neighbouring swales. That wind erosion subsequent to their formation was not the cause of this is indicated by the approximate parallelism of the bedding planes in the shell beds with the upper surface of the ridge they form, and also by the preservation of the swales between the ridges, which would have been partially obliterated by blown sand had the tops of the ridges been removed by the wind. Beach ridges formed at existing sea level are present in this district. They are quite distinct in form from the other ridges whose origin is in question.

Of particular significance, too, are the shape of the ridges in plan, and their spacing. Regular spacing of beach ridges, with intervening swales, can be brought about with a stationary sea level if a headland nearby is retrograding, so causing regular variation in the trend of the littoral currents. In the present example no such factor has been effective. The ridges have been "plastered" along an extensive stretch of flat coastline, from Williamstown to Werribee. Under these circumstances, and with a stationary sea level, beach ridges would have been piled successively one against the other, the intervening depressions being irregular and narrow. Actually, they are well spaced, and in places are separated by wide sandy flats, as for example south of the old brown coal mine. In addition, some of the ridges, especially in the Altona area, exhibit peculiar lobate or digitate projections from their landward sides (fig. 2). These projecting spits run off the main ridges towards the north-east. No beach ridges known to the author exhibit such features.

If the beach ridge hypothesis be rejected, it remains to indicate the mode of origin of the ridges and swales. The great breadth of the ridges compared with their height, the variation they show from shell beds to sand with included shells and pebbles, their regular spacing with low troughs between them, and their lobate landward edges suggest that they are raised banks such as are common off the existing beaches around the Bay. Examination of these banks has revealed that, as with the ridges, their seaward edges are typically smooth, but their landward edges are either lobate or furnished with oblique minor ridges running off at an acute angle into the troughs. Such banks occur in series, with well-defined troughs between them. In structure, external form, and spacing they are closely analogous to the Altona ridges.

It is therefore suggested that the underlying form of some at least of the ridges is that of submarine banks formed when the level of the sea was sufficiently high to cause it to flood over the basalt plains in the areas where the above described ridges occur. It appears probable that, either at this time or as the sea retreated, these banks were added to in places by the growth of beach ridges, but the shell beds near the Williamstown Racecourse, and the lobate ridges near Altona, are regarded simply as upraised submarine banks.

Shell Beds in Swampy Areas.

The elevation above high water mark, of marine shells *in situ* in black mud on the banks of Lake Truganina was determined as $3\frac{1}{2}$ feet. These muds contain paired valves of pelecypods, which are little disturbed and approximately in their position of growth. Comparable deposits now forming are found at half tide level or lower, and it is clear that emergence must have occurred, raising these marine shells above sea level. Bearing in mind the fact that similar black muds containing marine shells are now forming only below high tide level, it is also clear that the shell beds exposed at high tide level in the banks of the Kororoit Creek and those slightly above high tide level beneath the flats north of the Williamstown Racecourse must have also been uplifted.

Such shell beds are common along the eastern side of the Bay, and it may be emphasized that in deciding whether or not they have been uplifted, it is essential to remember that back-shore deposits and beach ridges, which can be built up above high tide level by normal progradation, have irregular stratification. They typically contain worn and broken shells, paired valves and complete delicate forms being rare or absent. Furthermore, they are never composed of shells set in fine mud, but consist of the coarser grades of sediment available along the shores.

Thus, the shell beds above mentioned, and similar occurrences at Werribee, Duck Ponds Creek, Corio Bay, and elsewhere (see Jutson, 1931, for details), which are now at or above high tide level, must have been uplifted. Indeed, at the Duck Ponds Creek the shell bed falls from about 5 feet above sea level near the Geelong road to sea level about a quarter of a mile downstream, and then passes beneath the waters of Corio Bay. The uplift at this locality was therefore tectonic. It has already been pointed out (Hills, 1938) that the raised Recent shell beds at Portarlington were probably elevated by earth movements, and Chapman (1929, Chap. XIV.) also favours the view that the emergence of the Recent deposits described by him was due to the same cause.

Point Lonsdale.

The thick shell beds that occur on the floors of the shallow salt and freshwater lakes in this district are most impressive. Concavo-convex shells are almost all arranged with their convex surfaces uppermost, and the deposits are well stratified, with gently inclined bedding planes. Dr. H. S. Summers informs me that a line of levels from the shores of Swan Bay to the top of the shell beds near the lake called Lake Lonsdale by Jutson, was run by him in collaboration with Mr. E. Broadhurst. The upper parts of the shell deposit are at least 1 foot above highest high water mark in Swan Bay. Furthermore, it is obvious in the field, as noted by Jutson, that the floors of some of the smaller lakes in the district, including the freshwater lake, are higher than the bed of Lake Lonsdale. Marine shell beds also occur around these lakes, so that the indications of uplift are further supported.

Raised Shore Platforms in Basalt.

From the south-eastern corner of the Rifle Butts at Williamstown, to the wheat stacks near the old Fort, the coast is formed of Newer Volcanic basalt. In this locality a well-defined low cliff marks the edge of the basalt plains, and between this cliff and the present shoreline is a basalt platform some 20-30 yards wide. This is not normally subject to wave attack, but parts of it were awash during the exceptionally high tides that accompanied the floods of December, 1934. The platform is grassed, and is covered with large loose boulders of basalt resembling those on the present beach. At the seaward edge of this platform there is in places a drop of about 3 feet to the present beach. Marine shells occur in black soil on the platform, and also in the joint planes of the basalt. The storm beaches built at the back of the existing beaches extend up for a short distance on to the seaward edge of the platform, but no further, and the suggestion is very strong that the platform is a raised

abrasion platform backed by a former sea cliff. The summit of the latter is approximately 5 feet above the platform, and this in turn 2 to 3 feet above the present abrasion platform.

Evidence that the latter is a true abrasion platform and not merely the original surface of a flow is afforded by the presence near the old fort of a small lava blister with its summit eroded away. No alternative explanation which would adequately explain the existence of the low scarp, here regarded as a former marine cliff, and also of the boulder-covered platform above high tide level can be suggested by the author.

III. Date of the Emergence.

The age of the emergence to which the above-described features may be ascribed is shown by the following lines of evidence:—

1. At Point Lonsdale and Sorrento the raised shell beds post-date the consolidated Pleistocene dunes.

2. Between Sorrento and Rye the raised shell beds and beach deposits post-date the consolidated Pleistocene dunes, but ante-date other calcareous dunes, which are not consolidated. The latter have yielded bones of a bird similar to a living form, but they are fixed by vegetation, and clearly were formed under physiographic conditions different from those now obtaining. It is suggested that there is no considerable difference in age between these dunes and the underlying raised beach deposits. This is indicated by the absence of weathering or erosion of the surface of the beach deposits upon which the dunes rest (pl. IV., fig. 2).

3. The palaeontology of the Altona shell beds has been discussed by Hall and Pritchard, by Grant and Thiele, and by Pritchard. Singleton (1935) has also referred to them. They contain only living species, and are regarded as Recent.

4. Chapman (see Jutson and Coulson, 1937) has shown that the Portarlington shell beds also contain only living species, and there is no good reason for regarding them as other than Recent.

5. None of the species collected by the author from the other shell beds is extinct, according to Mr. Singleton's identifications. The palaeontology of the shell beds was not, however, studied in detail.

6. The author agrees with Jutson that the uplift of the Kororoit Creek and Altona shell beds is of later date than that which caused the development of the high level terraces along the Moonee Ponds Creek and the Maribyrnong River.

The emergence is therefore regarded as Recent.

IV. Nature of the Emergence.

Differential elevation of Recent marine deposits has been noted at Portarlington, Duck Ponds Creek, and between Sorrento and Dromana, indicating that, at least in part, the emergence was due to tectonic movements of uplift.

Evidence of Recent emergence is so common along the Victorian coast, however, that a eustatic fall of sea level may be suspected of having contributed to it. Such Recent emergence has been described by others, or has been observed by the author at Marlo, the Ninety Mile Beach, Waratah Bay, Cape Patterson, Port Phillip Bay, Apollo Bay, Warrnambool, and Portland. Proof that eustatic movements have occurred must, however, await further detailed studies in Victoria and in other States.

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Fig. 1

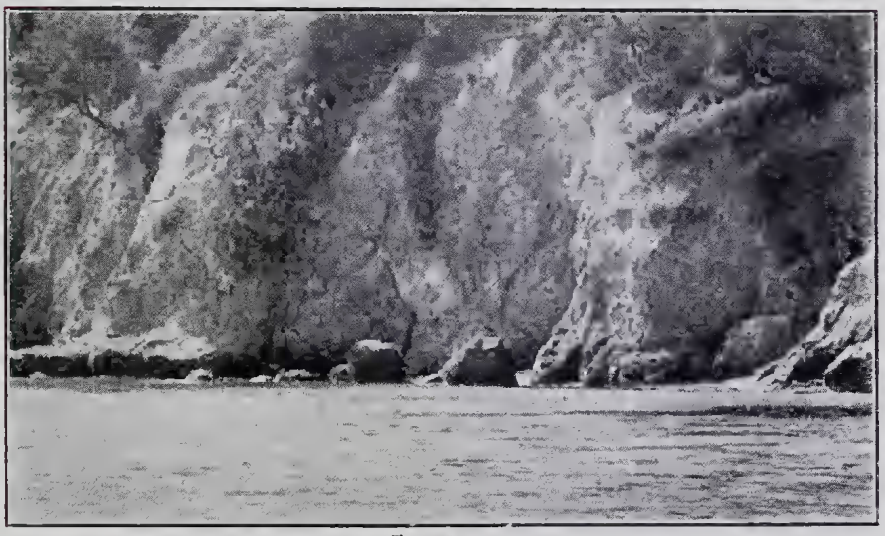

Fig. 2.

Fig. 3.

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Fig. 1.

Fig. 2.

Fig. 3.

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Explanation of Plates.

Plate III.

Fig. 1.—Raised abrasion platform in granite, overlain by pebbles and talus, Oliver's Hill, Frankston.

Fig. 2.—Raised shore platform in granite, Dromana Bay.

Fig. 3.—Raised abrasion platform and pebble bed covered with aboriginal kitchen midden. Note vegetated cliff in background. Between Grice's Creek and Davey Point.

Plate IV.

Fig. 1.—The cemented band in Pleistocene calcareous dune-rock, Point McArthur, Portsea.

Fig. 2.—Raised beach deposits showing normal stratification (in the excavation) overlain by calcareous dune sands. The remains of a fossil bird were obtained from the latter in the small upper excavation. West of Canterbury jetty, Rye.

Fig. 3.—Raised abrasion platform in Tertiary sandstone, overlain by pebbles. Fisherman's Point, Mornington.